(12) INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(54) Title: AMPHIBIOUS VEHICLE
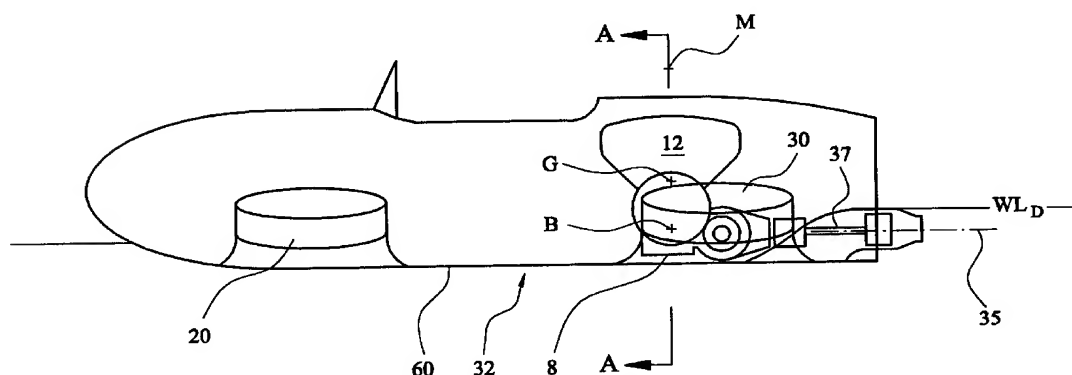
(57) Abstract: An amphibious vehicle (32) having a transverse mid- or rear-mounted engine (12) arranged to drive rear road wheels (30) and/or trhough an axial transmission (37), a marine propulsion unit (38), in which the engine (12) is so mounted in relation to the transmission (37) to the marine propulsion unit (38) that the bottom (8) of the engine is below the axis (37) of the transmission. This ensures an advantageous metacentric height which is preferably between 370 and 180 mm.

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Amphibious Vehicle

5   Practical amphibious vehicles generally have their engines mounted either centrally or in the rear of the vehicle so as to ensure a 'nose up' attitude when under way in marine mode. One such example of this conformation is as shown and described in Japanese Patent Publication No 63-093607 (Mazda Motor Corp). This Mazda proposal is for an amphibious vehicle having a transverse rear mounted engine arranged to drive selectively rear road

10   wheels and/or, through an axial transmission, a marine propulsion unit in this case a pump jet. More particularly the engine is mounted at least partly above the rear road wheel driving axles. The pump jet is driven by a shaft from a gearbox called a "transfer device". The transfer device is so designed to power front road wheels or the pump jet as required and is itself driven from the engine via a ring gear on a differential. The transfer device is mounted

15   ahead of the engine. The result of this Mazda conformation is that it is necessary to mount the engine above the pump jet driveshaft. This shaft is in turn central to the marine pump jet, which must be mounted to provide adequate ground clearance at the tail of the vehicle to give an adequate ramp angle when the vehicle is in road mode. Consequently the centre of gravity of the vehicle is higher than it would be for an equivalent purely marine craft. Again

20   because it is not possible to ballast an amphibious vehicle any increase in the height of the centre of gravity relative to the centre of buoyancy is significant when considering roll in marine mode for a vehicle with a low freeboard.

       It is therefore an object of the present invention to reduce the height of the centre of

25   gravity relative to the centre of buoyancy so as to increase the stability of the amphibious vehicle commensurate with adequate ground clearance.

       Accordingly the amphibious vehicle of the invention having a transverse mid- or rear- mounted engine arranged to drive rear road wheels and/or through an axial

30   transmission, a marine propulsion unit, is characterised in that the engine is so mounted in relation to the transmission to the marine propulsion unit that the bottom of the engine is below the axis of the transmission.

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The invention apart from assisting in ensuring "nose up" provides a conformation which is advantageous for an amphibious vehicle designed to plane.

5   Preferably, the bottom of the hull of the vehicle is designed so as to enable the vehicle to plane. For this purpose the wheels are arranged to be stowed in a raised position in marine mode as shown in our co-pending patent application no WO 95/23074.

Preferably the rear wheels are driven by the engine through a differential, a decoupler being provided between the differential and at least one rear wheel. The marine propulsion
10   unit is preferably driven by the engine and road wheel transmission, preferably also through the differential. A further decoupler may be provided between the differential and the marine propulsion unit. The differential is preferably mounted to the rear of the engine.

For an amphibious vehicle according to the invention it is preferable for the centre of
15   gravity to be no greater than 335mm, and more preferably not more than 275mm, above the centre of buoyancy so as to ensure an adequate righting moment. When it is designed to plane, the overall planing surface of the hull of the vehicle when planing is preferably between 1.4 and 14m^2, and more preferably between 6 and 7.6m^2. The centre of gravity is preferably not more than 510mm, and more preferably not more than 450mm, from the hull
20   bottom.

The metacentric height, beam at vehicle waterline, and waterplane area (where the vehicle is designed to plane) are useful parameters of vehicle stability. It is preferred that the metacentric height is between 370 and 180mm, and more preferably between 370mm and
25   290mm, depending on vehicle size, load, and configuration. Furthermore, the ratio of metacentric height to the beam at the vehicle waterline should preferably be between 0.10 and 0.33, and more preferably between 0.14 and 0.21. The ratio of metacentric height squared to planing area should preferably be between 0.004 and 0.052, and more preferably between 0.007 and 0.021; all of these ratios depending on vehicle size, load and
30   configuration and where appropriate, whether the vehicle is in displacement mode or planing mode.

Embodiments of the invention will now be described with reference to the accompanying drawings in which:-

Figure 1 is a diagrammatic side view of a first embodiment of the invention;

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Figure 2 is a perspective view from the rear and to one side of the powertrain of the first embodiment;

Figure 3 is a perspective view of an alternative powertrain to that shown in Figure 2

10   for a second embodiment of the invention;

Figure 4 is a side view of the first embodiment to show the centre of gravity relative the centre of buoyancy with an average loading, with the vehicle in displacement mode and wheels stowed in marine mode;

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Figure 5 is a side view similar to Figure 4, showing the vehicle planing;

Figure 6 is a cross section of the vehicle of Figure 4 taken at A-A of Figure 4 showing the buoyancy curve at the same average loading, wherein internal details are omitted for

20   clarity; and

Figures 7 to 9 are diagrams illustrating the dimensions listed in the data table on page 6 of the description.

Figure 7 is a similar view to figure 6, showing a transverse cross-section of the

25   vehicle;

Figure 8 is a further, simplified transverse cross-sectional view; and

Figure 9 is an external view similar to figure 4, showing the vehicle in displacement mode, and with wheels lowered.

These three figures are self explanatory, except for the dimension X, which is the

30   beam dimension averaged along the length of the vehicle. Clearly, the beam dimension will be smaller at the wheel arch cutouts than where the hull is full width.

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Figure 10 shows the smallest (132), typical (32), and largest (232) sizes of amphibious vehicle considered practical according to the conformation as claimed.

Figure 1, showing the first embodiment, shows a transverse engine 12 positioned towards the rear 33 of a planing amphibious vehicle 32. The engine 12, which drives through an in-line transmission 14, is arranged to drive either rear wheels 30 or marine propulsion unit (in this case a pump jet) 38 or both via differential 16 and decouplers 34 for the rear wheels (one decoupler may suffice) and shafts 18. The marine propulsion unit 38 is arranged to be driven via transfer gearbox 22 powered from differential 16, a further decoupler 36 and shaft 37 (Figure 2). Although a pump jet is shown a conventional marine screw propeller may be used. In a second embodiment shown in Figure 3, a transverse engine 12' is mounted at the rear of a vehicle similar to that in Figure 1. A transfer drive 40 mounted at one end 42 of the engine 12' provides drive to a transmission 44 positioned parallel with and adjacent to the engine 12'. This arrangement is commonly known as a "wrap around transmission". Transmission 44 is connected to an in-line differential 46.

Driveshafts 48 which provide drive to the rear wheels (not shown), similar to the arrangement of wheels 30 in Figure 1, are connected to decoupler(s) 50 driven from either side of the differential 46. A transfer gearbox 52 driven from differential 46 provides drive to a decoupler 54 which drives a pump jet 56 via shaft 37'.

Figures 4 and 6 show the relationship between centre of buoyancy B and centre of gravity G. As the vehicle 32 in its marine mode heels so that waterline WL_D (WL_s in Figure 6) becomes water wl, the centre of buoyancy moves along buoyancy curve x to centre of buoyancy b. The buoyancy curve x is centred on metacentre M. As the centre of buoyancy shifts from B to b, a righting moment develops, so that at b a righting moment equivalent to dimension GZ applies to right the vehicle. It will therefore be appreciated that the higher G is in relation to B; or as dimension BG increases; GZ will decrease. Thus by ensuring the bottom 8 of the engine 12 (12') is below the axis 35 of axial transmission shaft 37 (37'), in the present embodiment BG should be no greater than 275mm under normal loading conditions of a full tank of fuel, a driver and one passenger.

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Figure 4 also shows wheels 20, 30 raised in marine mode; which assists planing, as the wheels do not drag in the water. Note that due to the rearward weight bias, waterline WL_D (waterline in displacement mode) is not parallel to the vehicle wheelbase; so the vehicle sits "nose up" even when static.

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Figure 5 shows the vehicle planing. WL_F represents the water line at the front of the vehicle. Note that when planing, the vehicle sits on the water, rather than in it. WL_R represents the water level at the rear of the vehicle; as can be seen clearly in figure 6, a planing vehicle creates a trough in the water by its passage. WL_S is the water level in the
10   surrounding water, to the rear of the vehicle.

In figure 6, it can be seen why the beam at the waterline is wider when planing than it is in displacement mode. Each side of the vehicle has a step 70, 72 between front and rear wheel arches, which is provided to ease entry into the vehicle on land in the same fashion as
15   side steps on four-wheel-drive vehicles. These steps are submerged in displacement mode, when the vehicle is simply floating (figure 7). When the vehicle is planing, although there is a gradation in conditions between front and rear of the vehicle, these steps are on the water line in the centre part of the vehicle.

20   In practice the following parameters apply, for the vehicle shown in figure 1:-

	STATIC	ON PLANE
Length of Waterline	4.47m	3.4m
Beam of Waterline	1.85m	2.0m
Waterplane Area, nominal (A_p)	8.3m^2	6.8m^2

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By having shaft 37 (37') above the bottom 8 of the engine, the engine can be lower. This improves the drive angle to the rear wheels and the following improvements result:-

(i)   improved road handling – less roll and better grip when cornering

(ii)   improved marine handling when planing

30   (iii)   improved marine stability when in displacement mode

(iv)   less tendency to heel when turning in marine mode

(v)   in planing mode better lateral stability without having to increase beam (noting that increasing the beam can increase drag at high speed, ride hardness at high speed and roll in a seaway all when planing)

(vi)   in displacement mode, better lateral stability without increase in beam; which would increase vessel cost, and reduce the roll angle at which freeboard is exceeded and swamping occurs; and could exceed a practical width for the automotive road-going mode.

Further detailed parameters apply for the same embodiment but with different loading conditions as follows (noting that the centre of gravity rises by about 33mm when wheels are raised in planing mode; and that the centre of buoyancy is at the same longitudinal and lateral location as the centre of gravity.):-

Loading Condition	Case 1:unloaded	Case 2: driver +Fuel+ 2 Passengers + Luggage
Mean beam – mm (X)	1326	1332
Beam at waterline, static – mm (X_s)	1830	1850
Beam at waterline, planing – mm (X_p)	N/A	2000
Deadrise – degrees (θ)	9	9
C of G above hull bottom – mm (Z_{cg})	401	395
C of G from stern – mm (S_{cg})	1680	1680
Draft – mm (D)	301	330
Water plane length, static – mm (L_{wp})	4400	4470
Small immersion due to tilt – mm (h)	50.0	50.2
Depth of deadrise – mm (dr)	105.0	105.5
Wall immersion level – mm (dw)	196.0	224.5
Mean cross section area immersed– mm^2 (A_o)	329510	369313
Centre of buoyancy height – mm (Z_{bo})	174.9	189.7
Moments about hull base – m^3 ($A_o Z_{bo}$)	0.0576	0.0701
Metacentric height – mm (M_z)	363.5	328.0
Centre of buoyancy to metacentre (BM)	589.6	533.3
Ratio of metacentric height to waterline beam, static (M_z / X_s)	0.199	0.178

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Ratio of metacentric height to waterline beam, planing (M_z / X_p)	N/A	0.164
Ratio of (metacentric height) squared to planing area (M_z^2 / A_p)	N/A	0.0158

From these parameters, it can be seen that for this embodiment, the centre of gravity is not more than 450mm from the vehicle hull bottom. Further, the metacentric height is within the range from 370mm to 290mm, dependent on vehicle load and configuration.

The ratio of metacentric height to beam at the vehicle waterline is readily calculated from the above data, and is found to be between 0.14 and 0.21, dependent on vehicle load and for a planing vehicle with retractable wheels, on vehicle configuration, and whether it is in displacement mode or in planing mode. This ratio is a useful indicator of lateral stability on water, where a high ratio indicates high stability. For comparison, K.J. Rawson and E.C. Tupper, in "Basic Ship Theory" Volume 1, Section 4, give a typical value for a ship of 0.143. In the present case, this amphibious vehicle has an improved stability over the ship described by Rawson and Tupper.

The ratio of metacentric height squared to waterplane area is particularly helpful for a planing vehicle, as an indication of stability in both lateral and longitudinal axes. This ratio is readily calculated from the above data, and is found to be between 0.009 and 0.021, with identical provisos to the above; in that this ratio depends on vehicle load and for a planing vehicle with retractable wheels, on vehicle configuration, and whether it is in displacement mode or in planing mode.

The above parameters are as mentioned above, calculated for an amphibious vehicle 32 according to figure 1, which is also shown as a typical amphibious vehicle according to the claims, in figure 10. The smallest amphibious vehicle considered practical according to the conformation as claimed is shown at 132 in figure 10. It is considered that its centre of gravity would be approximately 60mm higher than for vehicle 32, and its planing area 1.4-3m², dependent on hull design. Its metacentre would be some 50mm lower than for vehicle 32, and its static beam at the waterline 1.2m. The planing beam at the waterline would be 0.9m.

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From these parameters, the centre of gravity for such a vehicle would not be greater than 335mm above the centre of buoyancy, and not more than 510mm from the hull bottom. The metacentric height will vary between 260mm and 180mm; and its ratio to beam at waterline will vary between 0.14 and 0.33. The ratio of metacentric height squared, to
5   planing area will vary from 0.011 to 0.052.

Similarly, the largest amphibious vehicle considered practical according to the conformation as claimed is shown at 232 in figure 10. Its centre of gravity would be 40mm higher than for vehicle 32, and its planing area 10-14m^2. Its metacentre would be at the same
10 height as for vehicle 32. The static beam at the waterline would be 2.3m, and the planing beam at the waterline 2.4m.

From these parameters, the centre of gravity for such a vehicle would not be greater than 315mm above the centre of buoyancy, and not more than 490mm from the hull bottom.
15 The metacentric height will vary between 330mm and 250mm; and its ratio to beam at waterline will vary between 0.10 and 0.14. The ratio of metacentric height squared, to planing area will vary from 0.004 to 0.109.

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CLAIMS

1. An amphibious vehicle having a transverse mid- or rear- mounted engine arranged to drive rear road wheels and/or through an axial transmission, a marine propulsion unit, characterised in that the engine is so mounted in relation to the transmission to the marine propulsion unit that the bottom of the engine is below the axis of the transmission.

2. The vehicle of Claim 1 having a bottom enabling planing in a marine mode and road wheels arranged to be stowable in a raised position for marine travel.

3. The vehicle of Claim 1 or 2 wherein the rear wheels are driven by the engine through a differential, a decoupler being provided between the differential and at least one rear wheel.

4. The vehicle of Claim 3 wherein the marine propulsion unit is arranged to be driven from the engine and road wheel transmission.

5. The vehicle of Claim 4 wherein the marine propulsion unit is arranged to be driven from the engine, road wheel transmission, and differential.

6. The vehicle of Claim 5 wherein the marine propulsion unit is arranged to be driven from the engine, road wheel transmission, and differential, via a further decoupler.

7. The vehicle of any one of Claims 3 to 6 wherein the differential is mounted to the rear of the engine.

8. The vehicle of any one of Claims 1 to 7 wherein the centre of gravity is no greater than 335mm above the centre of buoyancy.

9. The vehicle of Claim 8 wherein the centre of gravity is no greater than 275mm above the centre of buoyancy.

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10. The vehicle of any one of Claims 2 to 9 wherein the bottom has a planing surface between 1.4 and 14m^2.

11. The vehicle of Claim 10 wherein the bottom has a planing surface between 6 and 7.6m^2.

12. The vehicle of any one of Claims 2, 10, or 11, wherein the centre of gravity of the vehicle is not more than 510mm above the vehicle hull bottom.

13. The vehicle of Claim 12, wherein the centre of gravity of the vehicle is not more than 450mm above the vehicle hull bottom.

14. The vehicle of Claim 2 or any one of Claims 3 to 13 when dependent on Claim 2, wherein the metacentric height is between 370 and 180mm, dependent on vehicle size, load, and configuration.

15. The vehicle of Claim 14, wherein the metacentric height is between 370 and 290mm, dependent on vehicle load and configuration.

16. The vehicle of any one of Claims 2, 10, or 11, wherein the ratio of metacentric height to beam at the vehicle waterline is between 0.10 and 0.33, dependent on vehicle size, load, and configuration, and whether the vehicle is in displacement mode or in planing mode.

17. The vehicle of Claim 16, wherein the ratio of metacentric height to beam at the vehicle waterline is between 0.14 and 0.21, dependent on vehicle load and configuration, and whether the vehicle is in displacement mode or in planing mode.

18. The vehicle of any one of Claims 2, 10, or 11, wherein the ratio of metacentric height squared to waterplane area is between 0.004 and 0.052, dependent on vehicle size, load, and configuration, and whether the vehicle is in displacement mode or in planing mode.

19. The vehicle of Claim 18, wherein the ratio of metacentric height squared to waterplane area is between 0.007 and 0.021, dependent on vehicle load and configuration, and whether the vehicle is in displacement mode or in planing mode.

20. An amphibious vehicle substantially as described with reference to any one or more of Figures 1 to 10 of the accompanying drawings.

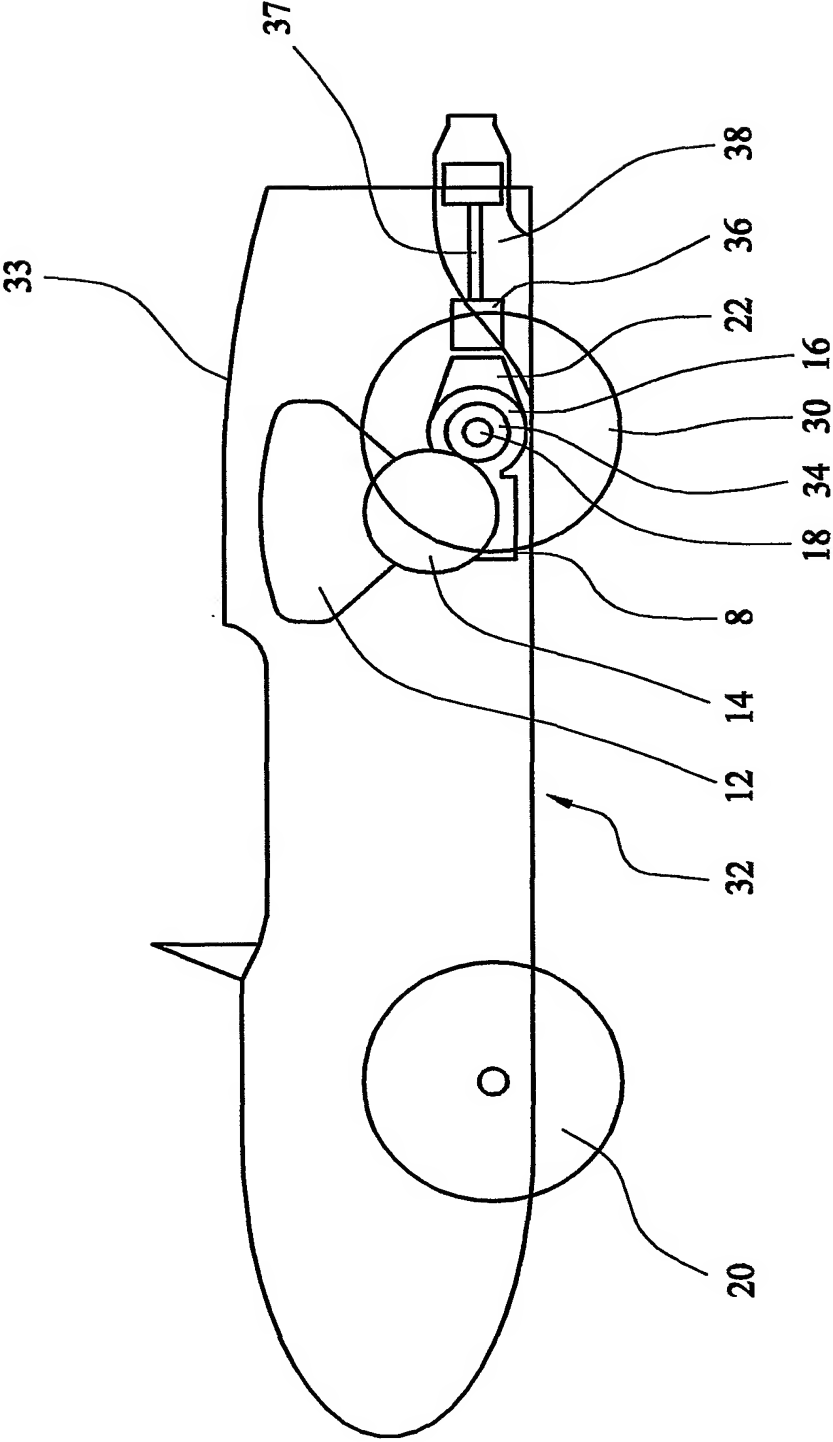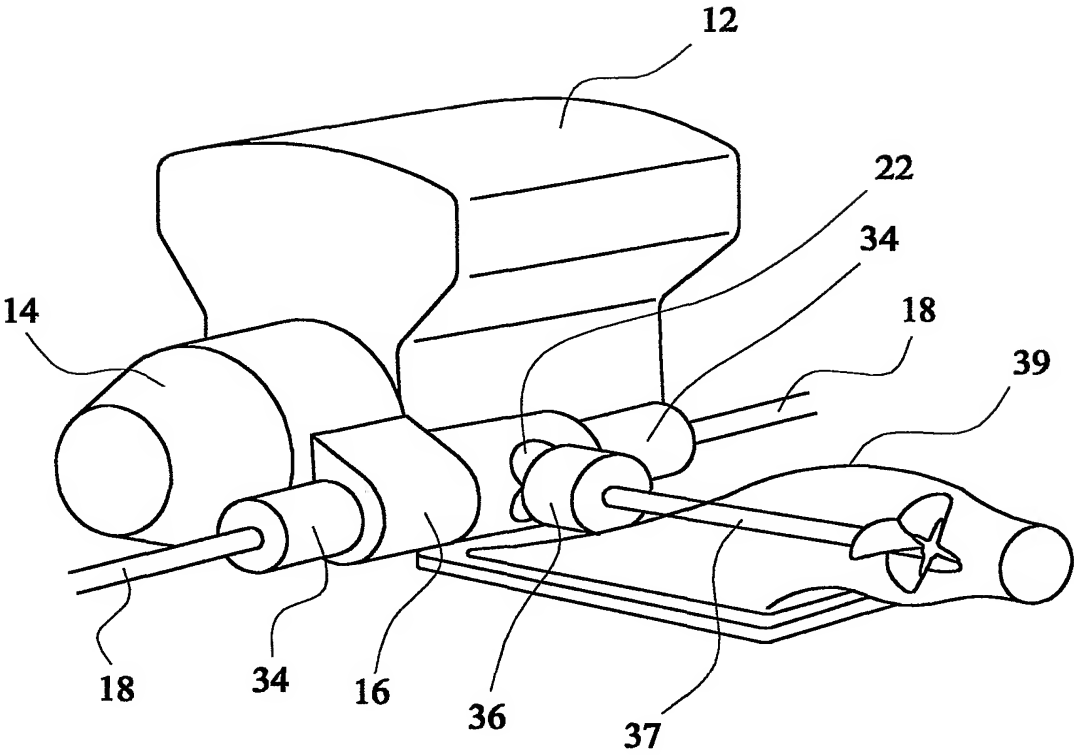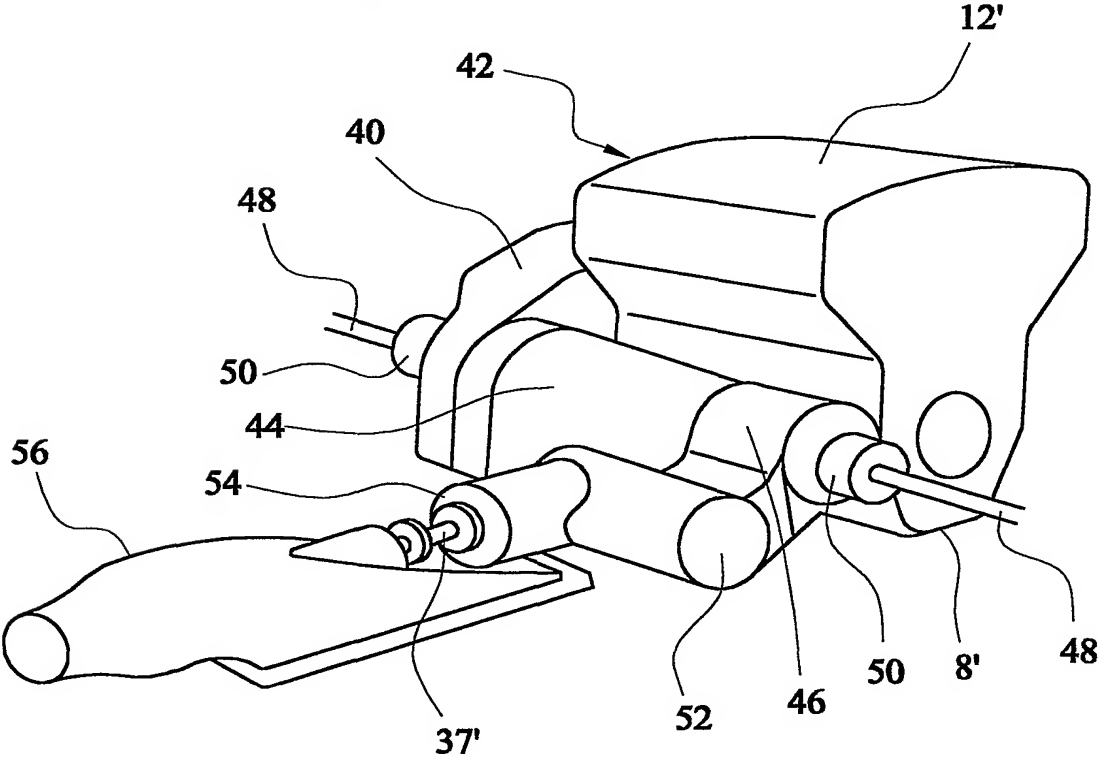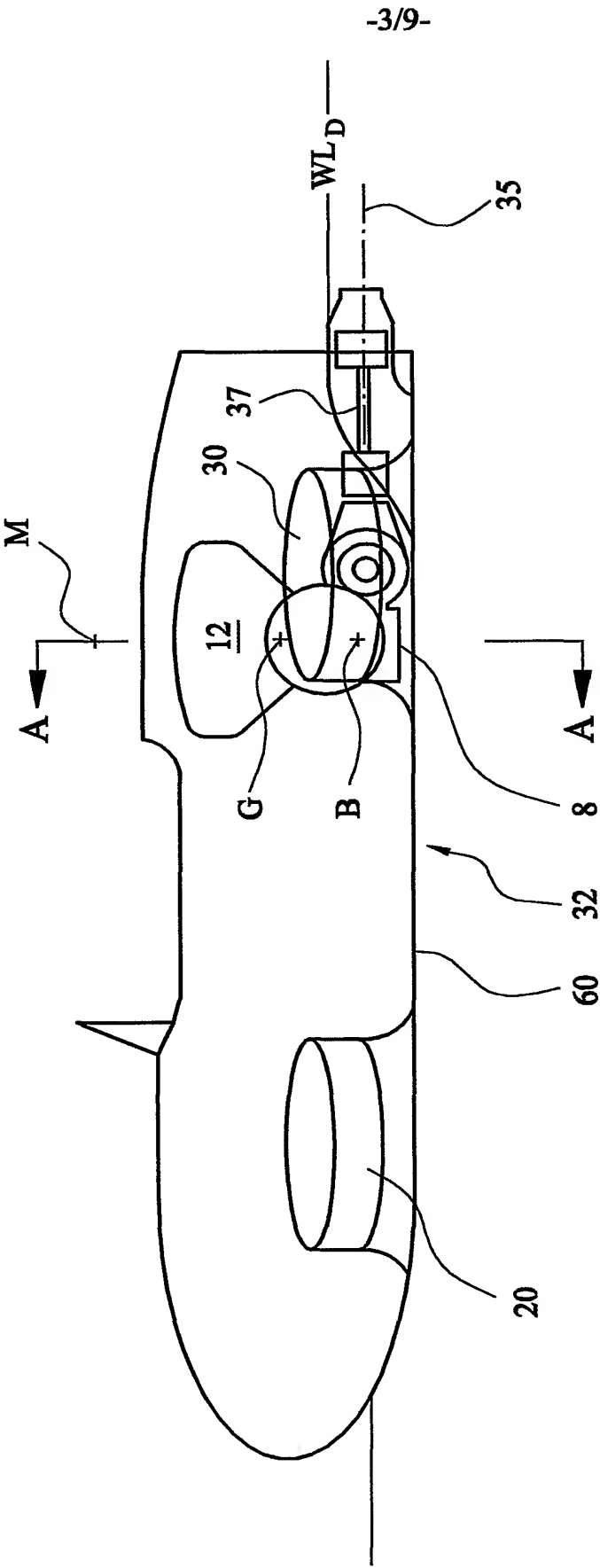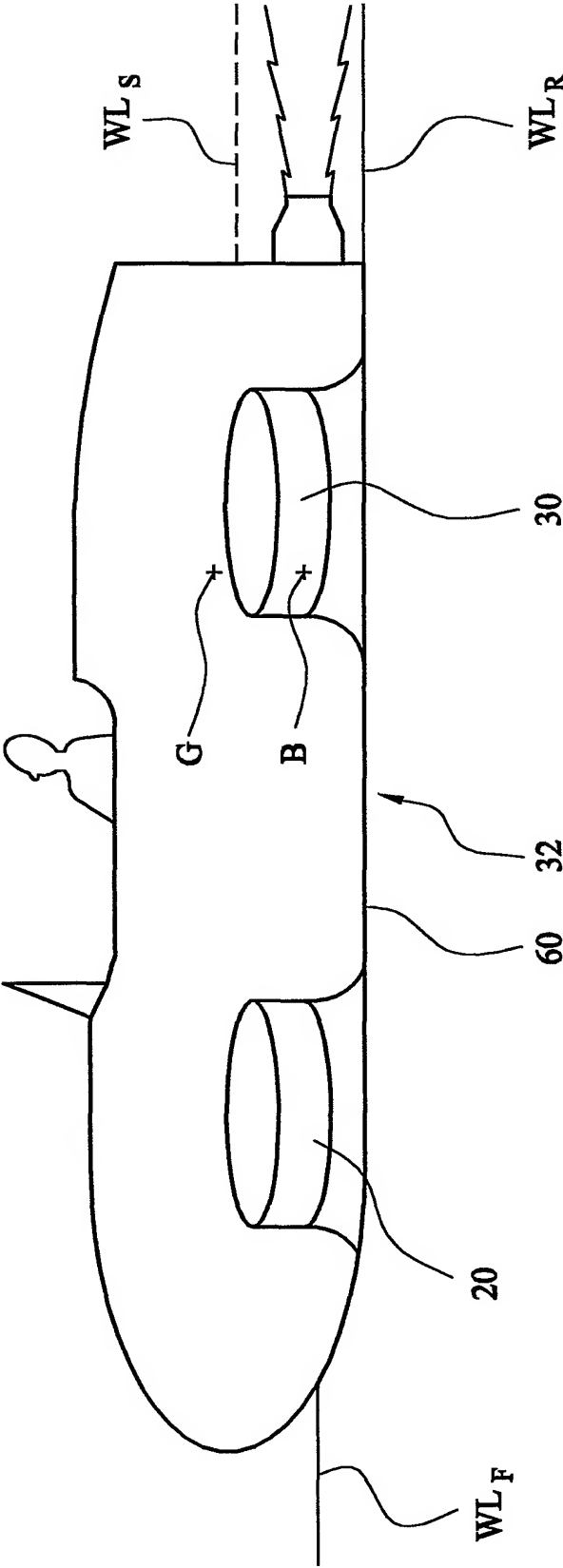FIG. 1
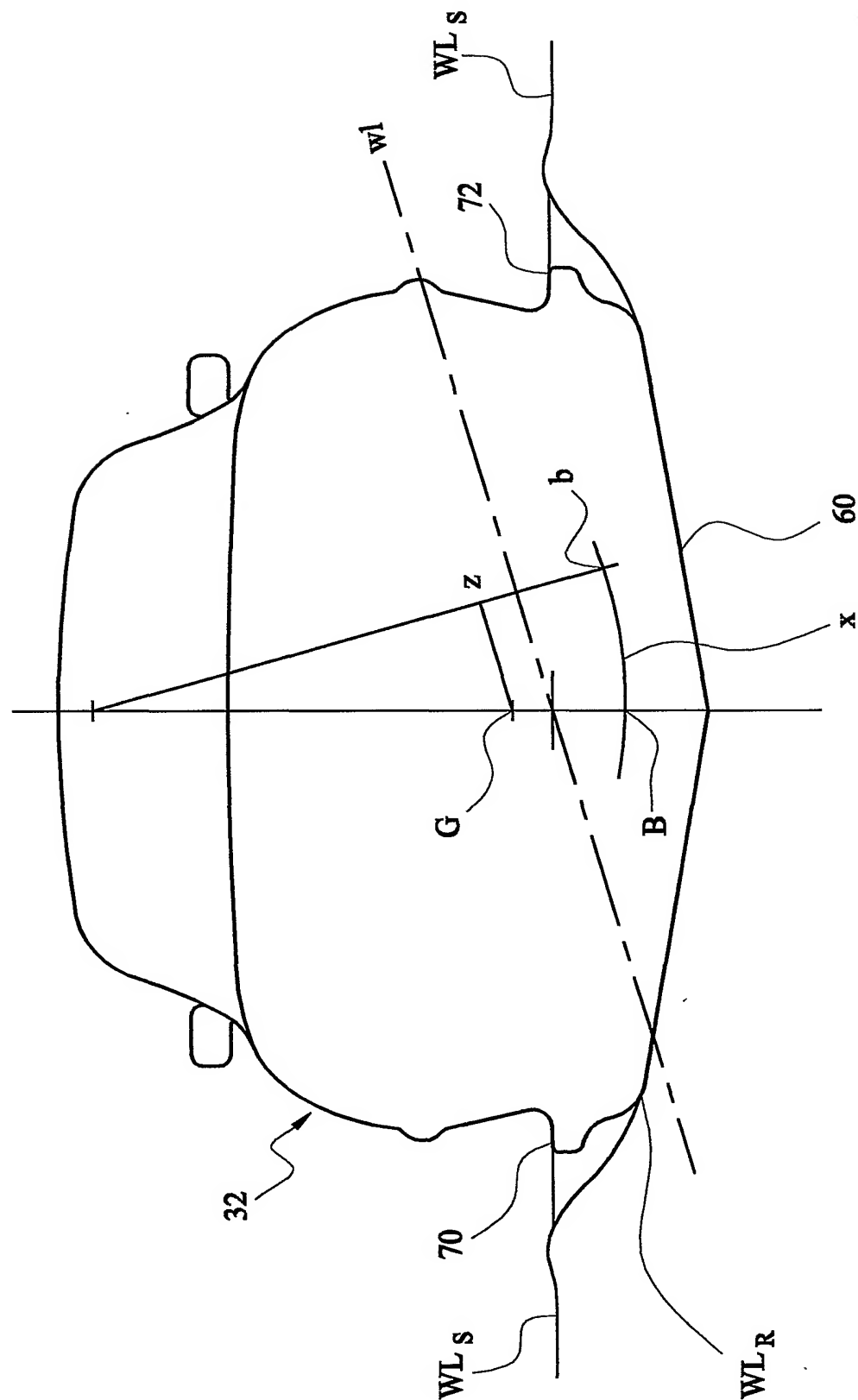
FIG. 2

FIG. 3

FIG. 4

WL_S

WL_R

G

B

30

32

60

20

WL_F

FIG. 5

FIG. 6

FIG. 7

FIG. 8
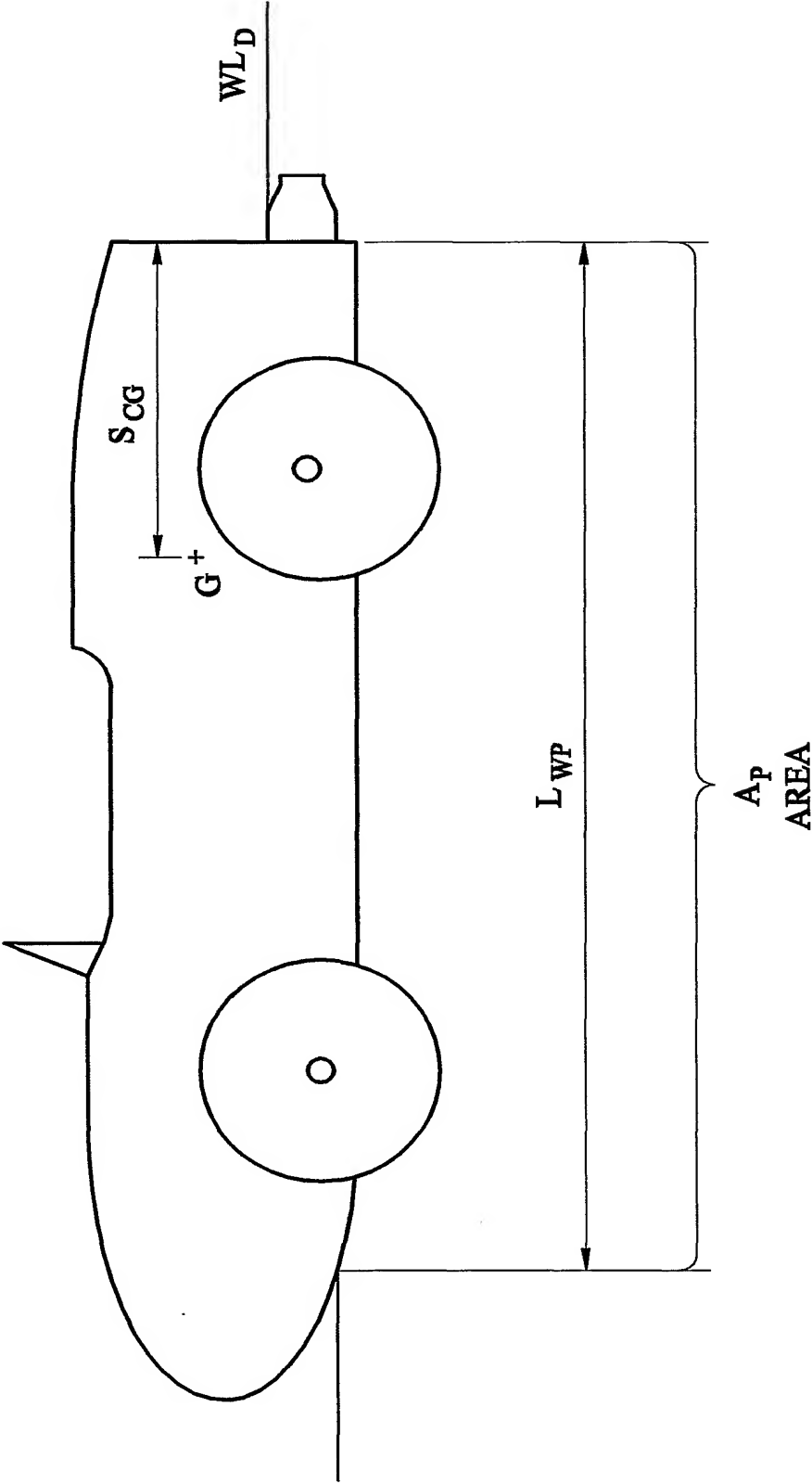
FIG. 9
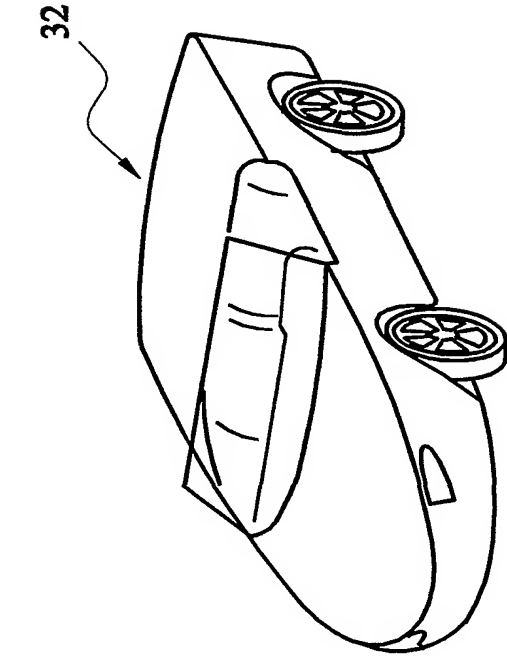
FIG. 10
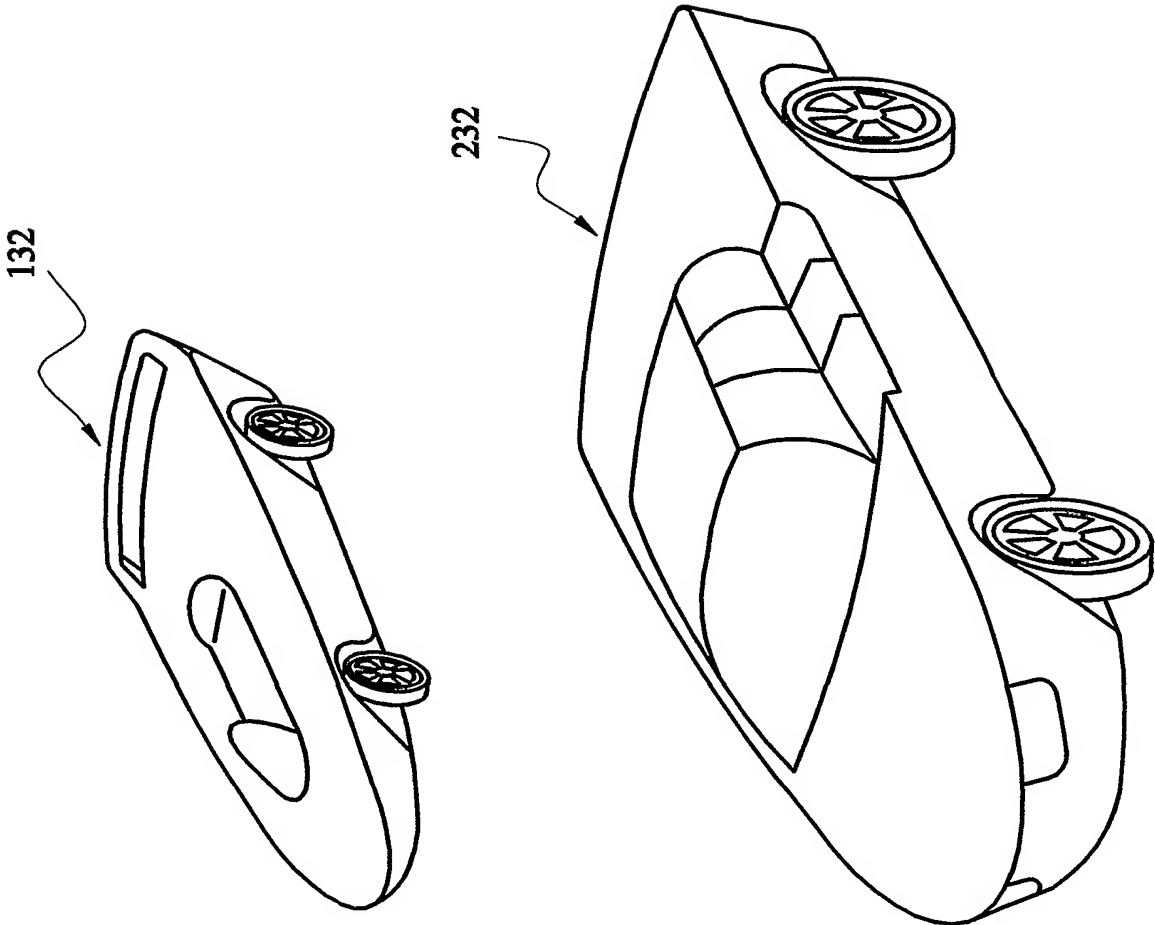
INTERNATIONAL SEARCH REPORT

A. CLASSIFICATION OF SUBJECT MATTER
IPC 7   B60F3/00

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7   B60F   B60K

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, PAJ, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category °	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 3 613 816 A (GUTBROD WALTER) 19 October 1971 (1971-10-19) figures 1,2	1,20
A	PATENT ABSTRACTS OF JAPAN vol. 012, no. 332 (M-738), 8 September 1988 (1988-09-08) & JP 63 093607 A (MAZDA MOTOR CORP), 23 April 1988 (1988-04-23) cited in the application abstract	1

☐ Further documents are listed in the continuation of box C.   ☒ Patent family members are listed in annex.

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Date of the actual completion of the international search	Date of mailing of the international search report
30 November 2001	06/12/2001

Name and mailing address of the ISA	Authorized officer
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INTERNATIONAL SEARCH REPORT

formation on patent family members

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